Tunable RF and Analog Circuits Using On-Chip MEMS Passive Components

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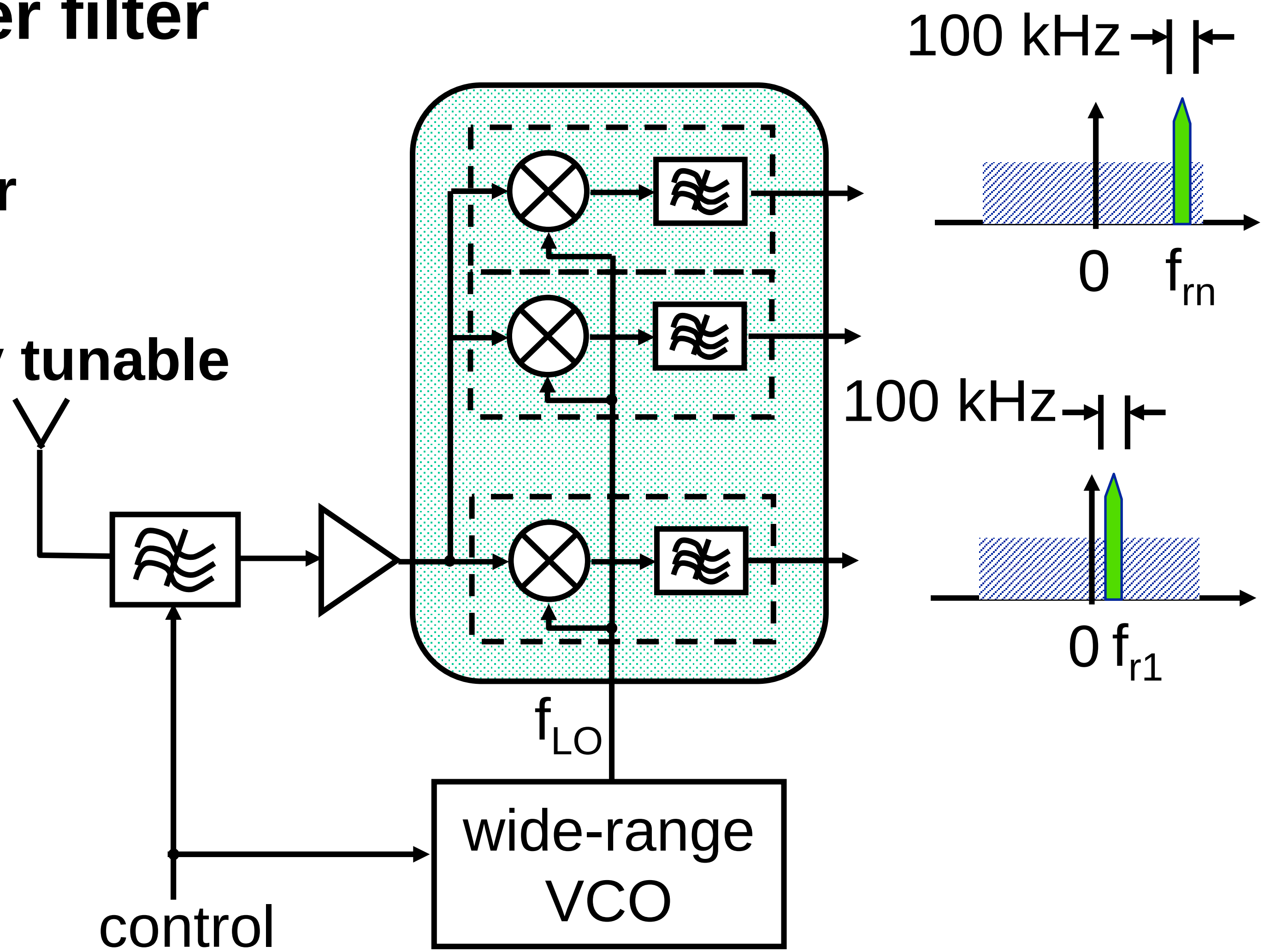
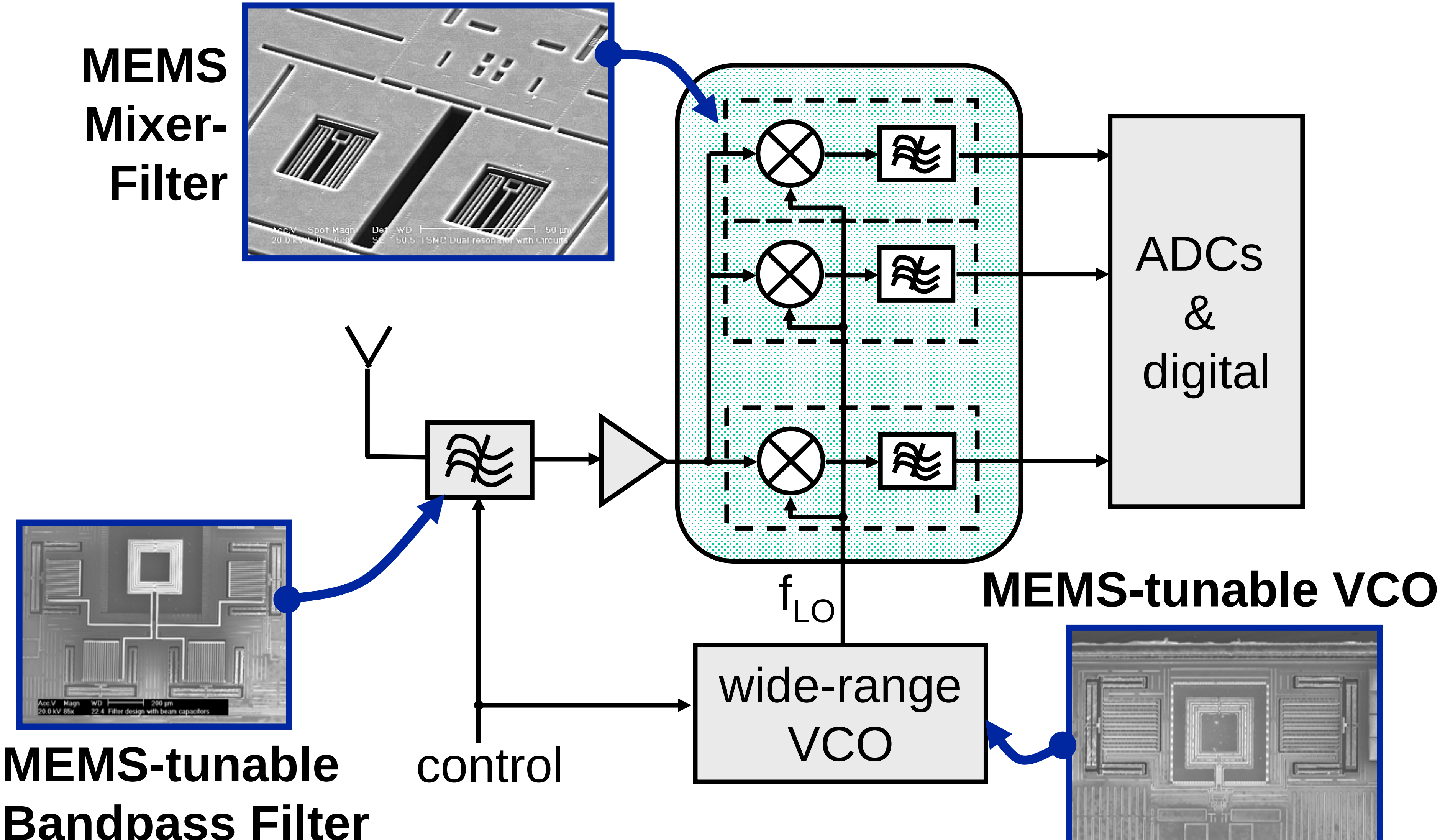
MEMS Channel Selectable Architecture

- **MEMS mixer filter**
  - **High Q**
  - **Low power**
  - **Low area**
  - **Not widely tunable**
- **Mixer filter array**
  - **High Q *and* channel select**



Integrated RF-MEMS-Enhanced Receivers



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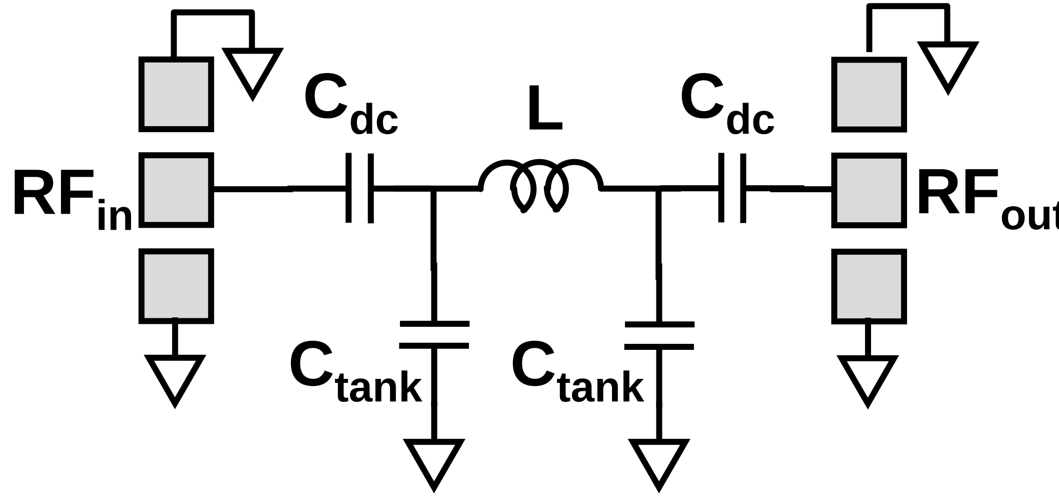
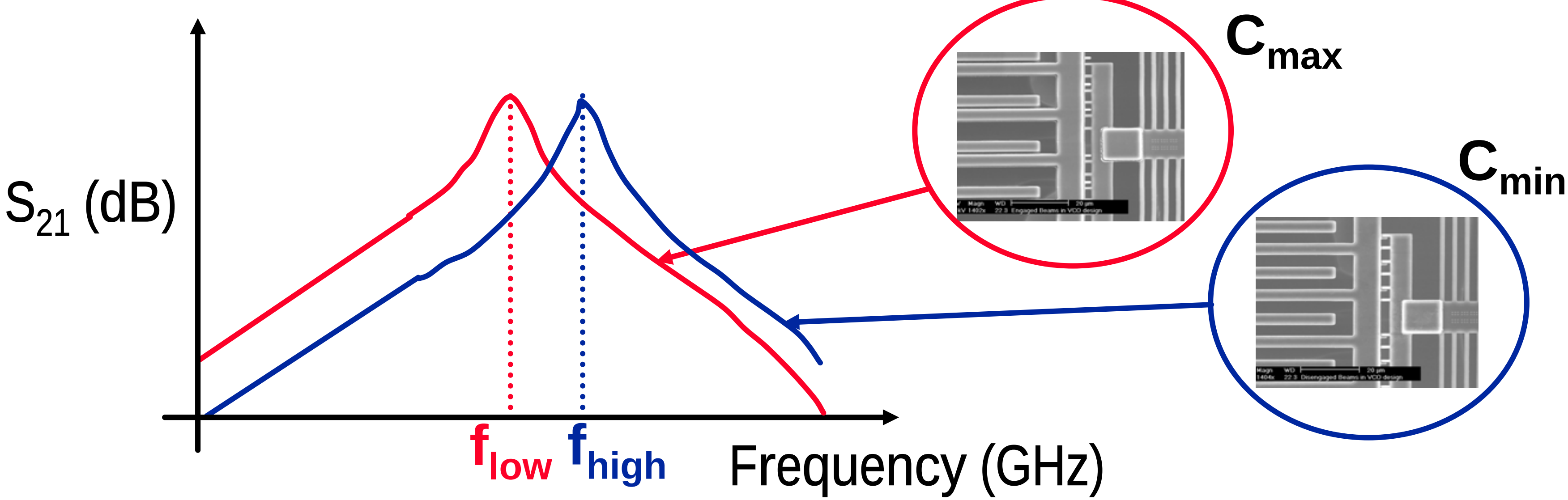
Reconfigurable Image-Reject Filters

Initial π-Filter design

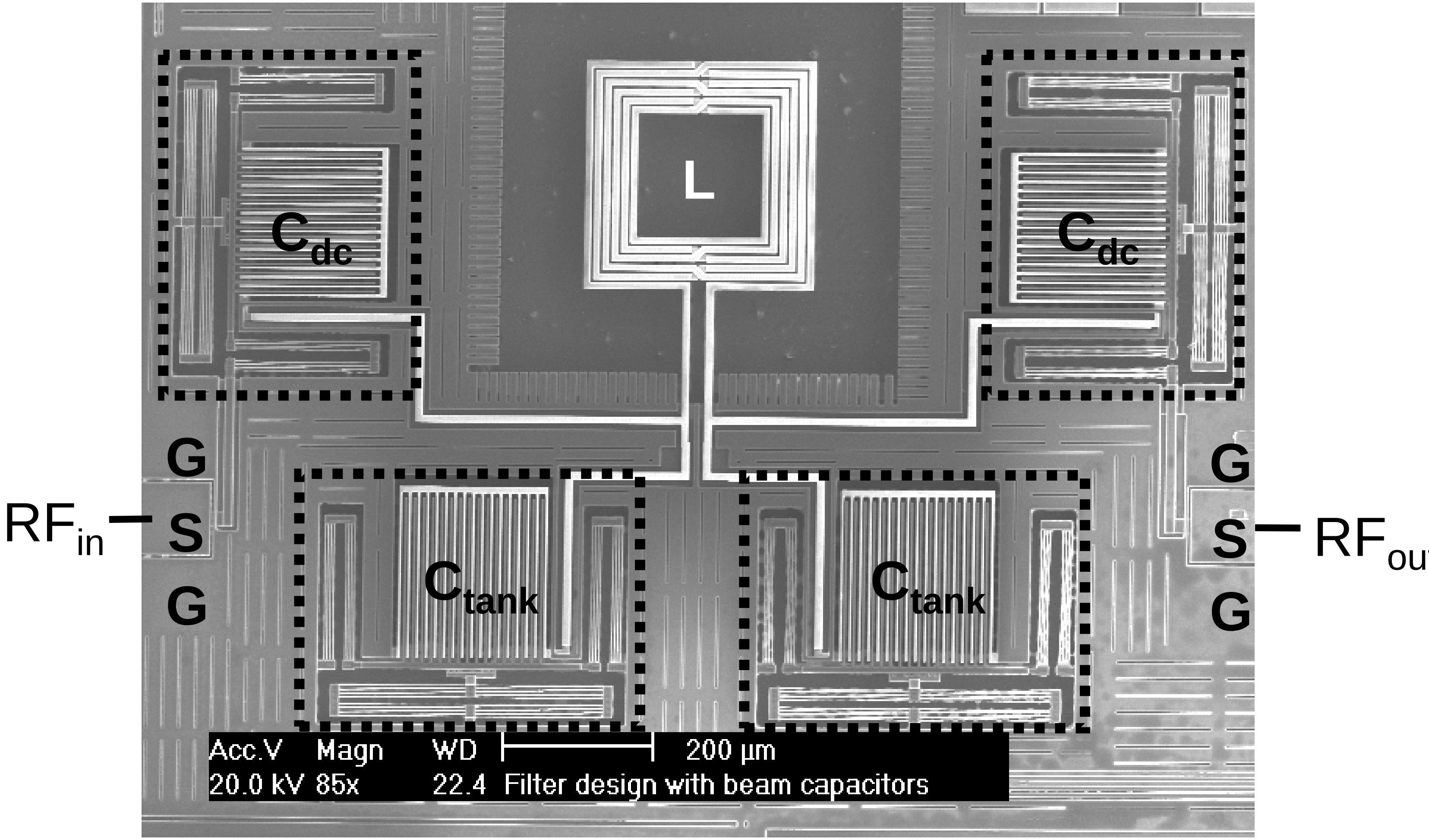
- f_{low} = 1.7 GHz
- f_{high} = 2.6 GHz



Latched RF MEMS capacitive switches



RF MEMS LC Filter in Jazz SiGe60 BiCMOS

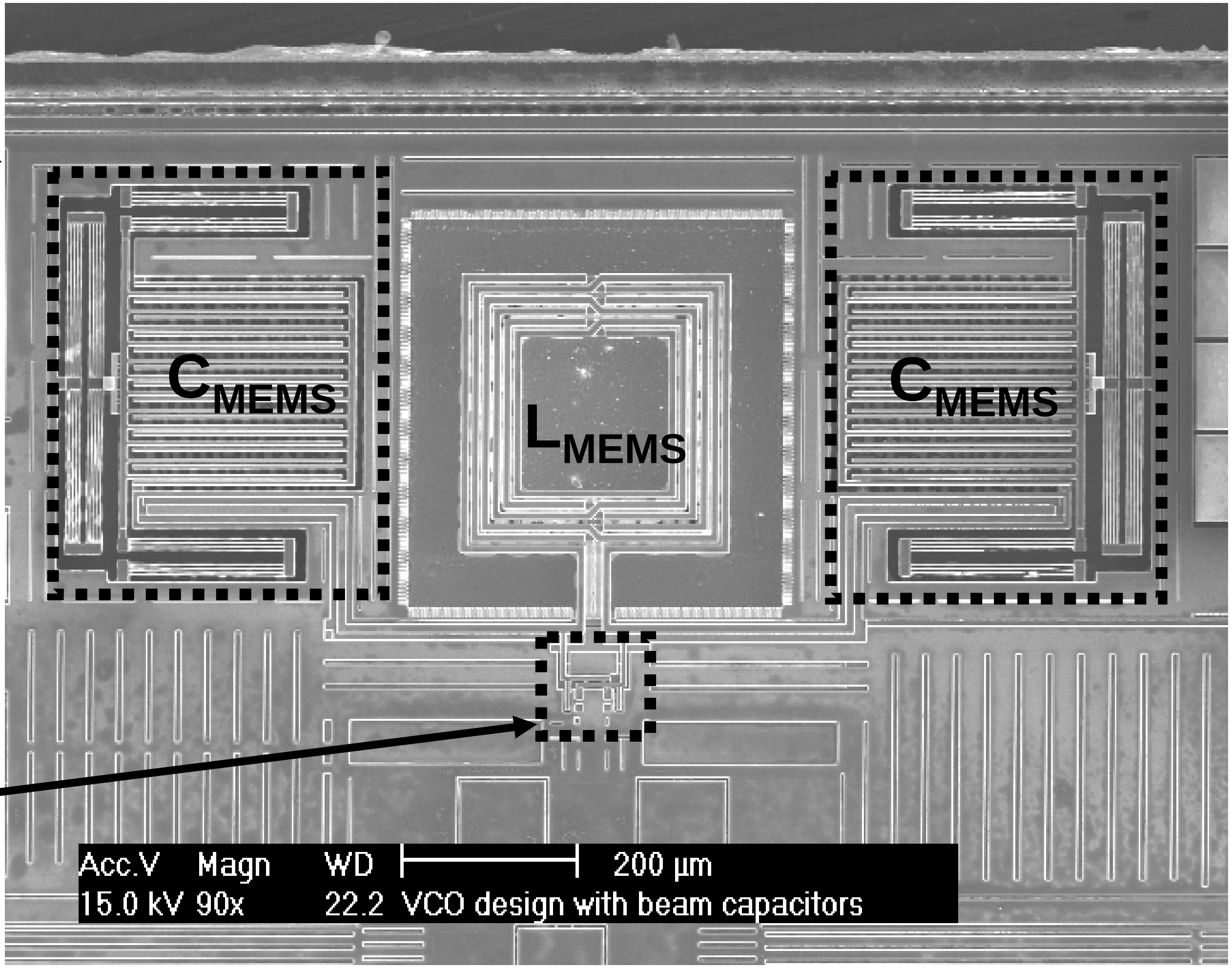


250 fF < C_{dc} < 550 fF; 300 fF < C_{tank} < 800 fF

Measured reconfigurable switching range = 850 MHz

RF MEMS VCO in Jazz SiGe60 BiCMOS

area = 0.87 mm^2



active circuit

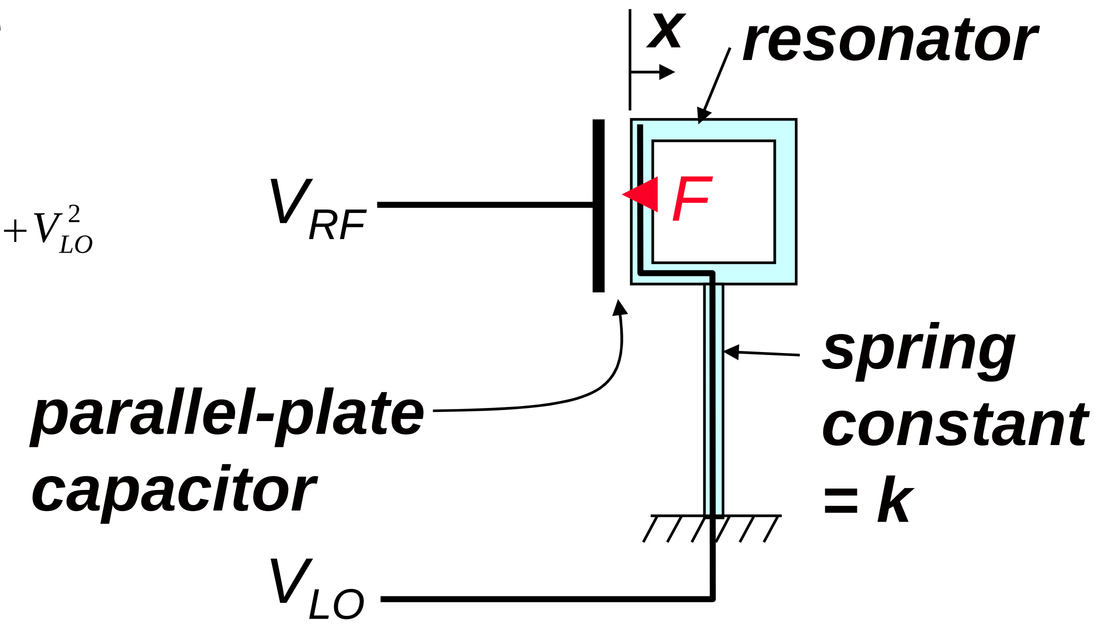
L_{MEMS} = 6.25 nH; 180 fF < C_{MEMS} < 1 pF

f_0 = 2.844 GHz, 122 dBc/Hz @ 1 MHz offset & 2.7 mW

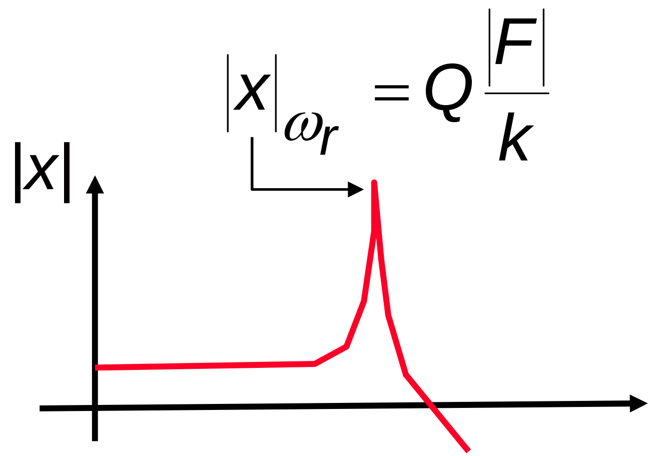
MEMS Mixer-Filter Principle

- Electrostatic force works as mixer

$$F = \frac{1}{2}\frac{dC}{dx}(V_{RF} - V_{LO})^2 \propto V_{RF}^2 \underbrace{-2V_{RF}V_{LO}}_{\text{Mixer term}} + V_{LO}^2$$

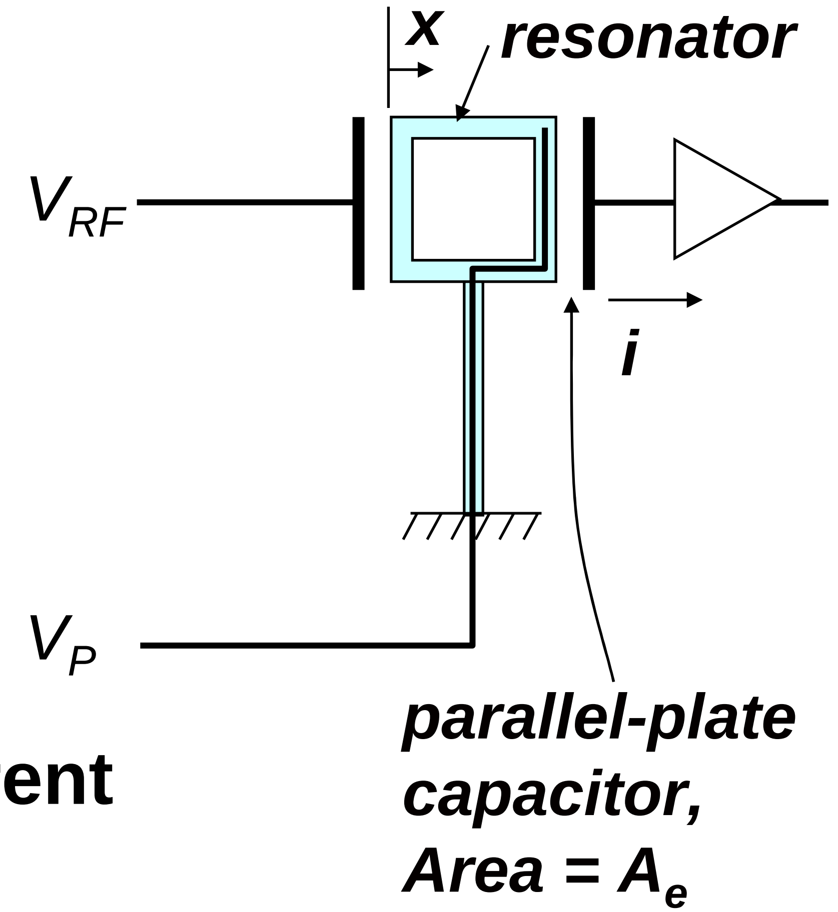


- Force creates mechanical displacement, *x*
- Direct down conversion of RF to MEMS resonance
  - Resonant filter effect



Mixer-Filter Output

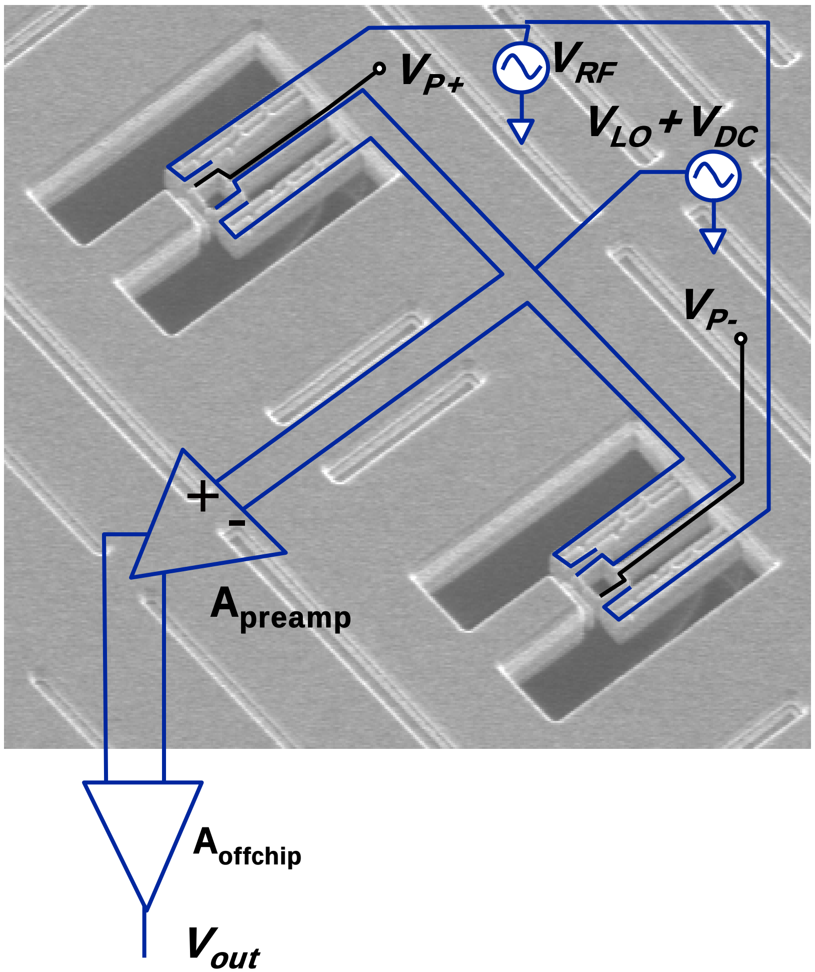
- DC “polarizing” voltage, V_P, across output gap
- Displacement current, proportional to:
  - V_P
  - velocity
  - $V_{LO} \times V_{RF}$
- Pre-amplifier detects current

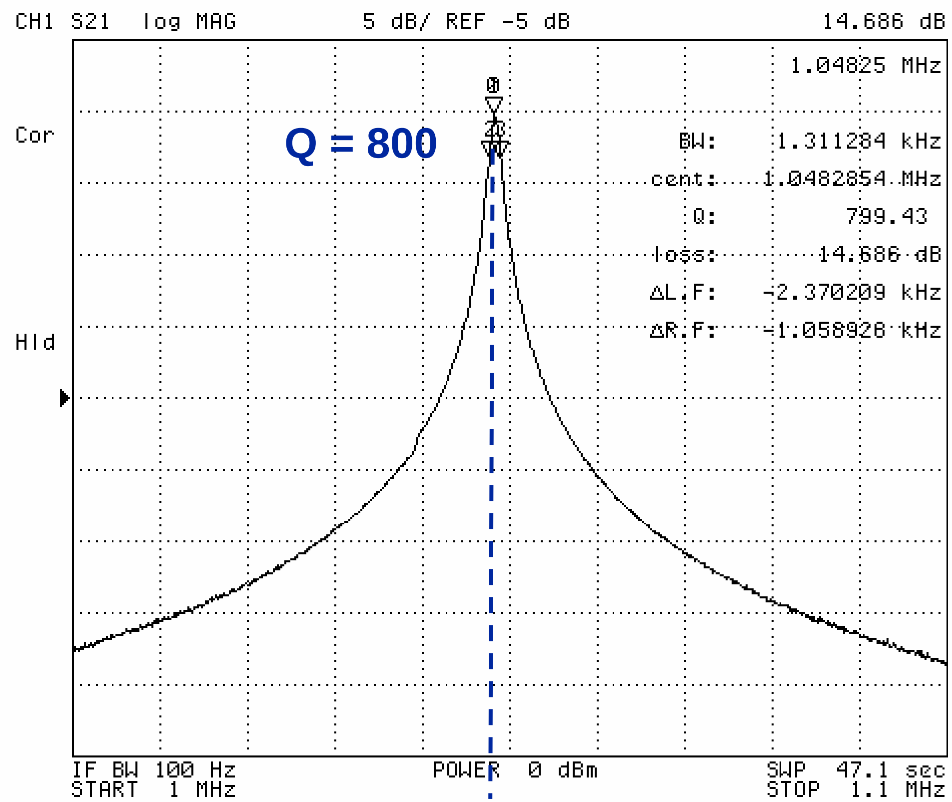


$$\left| i \right|_{\omega_r} = V_p \frac{dC}{dx} \frac{dx}{dt} = \frac{k(\varepsilon_o A_e)^2}{2Q\omega_r g^4} V_p V_{LO} V_{RF}$$

CMOS-MEMS Resonator Q

in Jazz 0.35 µm CMOS



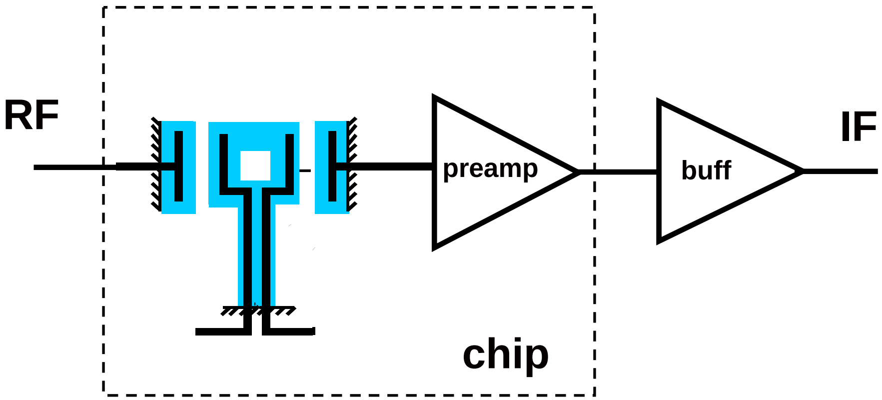


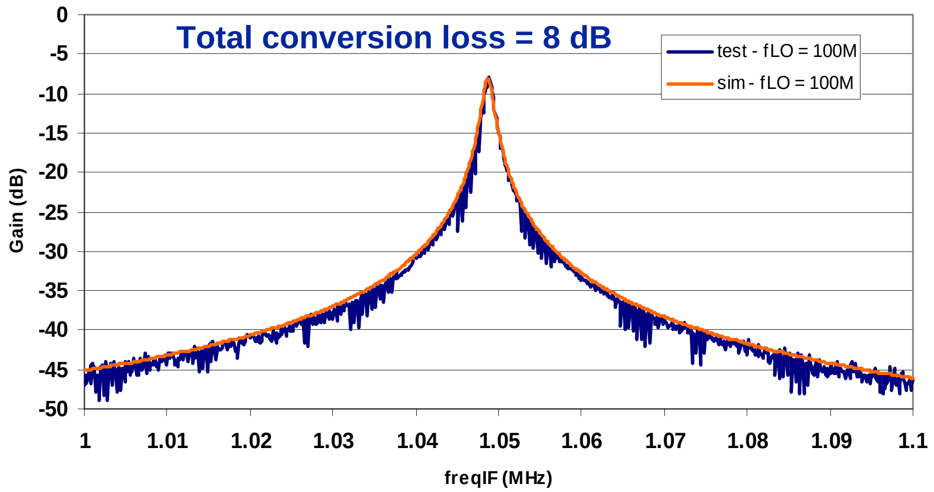
f_r = 1.05 MHz

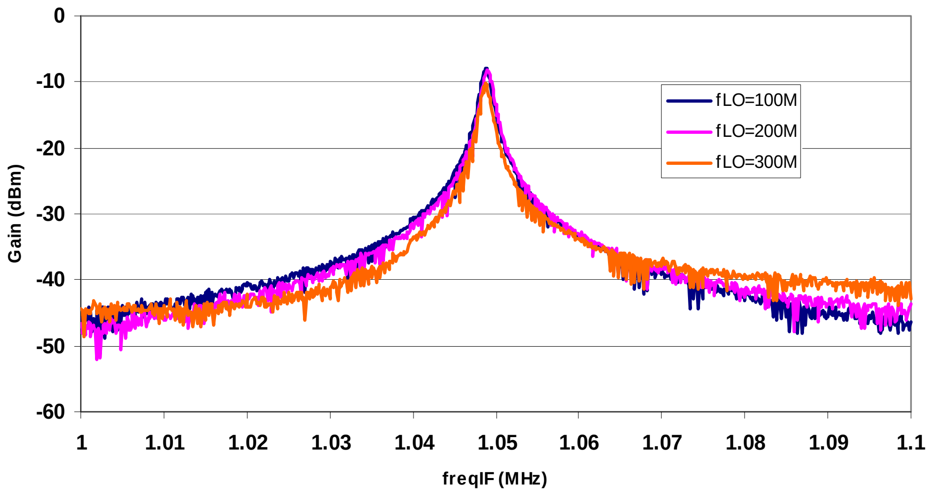
Mixer-Filter Characteristics

- **Inputs:**

  V_{LO} = 1.4 V (peak)
  V_{P+} = 10V, V_{P-}=$V_{preamp-}$
- **LO stepped 10 - 400 MHz**
- **Measured results are well-matched to simulated results**







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